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JAPANESE [JP,2001-127351,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE INVENTION TECHNICAL PROBLEM MEANS DESCRIPTION OF DRAWINGS DRAWINGS

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] Two or more 1st pads which have been arranged discretely and formed with the oxide superconducting material on the main front face of the 1st dielectric substrate and said 1st dielectric substrate, The touch-down electric conduction film which has been arranged on the main front face of said 1st dielectric substrate, and was formed with the oxide superconducting material, The front face of said touch-down electric conduction film is arranged on the front face of a wrap dielectric film and said dielectric film. Superconducting circuit equipment of said 1st pad with the sum total of the thickness of said touch-down electric conduction film, said dielectric film, and said superconducting circuit pattern it is formed with an oxide superconducting material, have the superconducting circuit pattern connected to said 1st pad, and smaller than height.
[Claim 2] Superconducting circuit equipment according to claim 1 by which said touch-down electric conduction film covers the front face of 1st at least one pad among said two or more 1st pads, and is electrically connected to the 1st pad concerned.
[Claim 3] Furthermore, it is discretely arranged on the main front face of the 2nd bigger dielectric substrate than said 1st dielectric substrate and said 2nd dielectric substrate. two or more 2nd pads formed with the oxide superconducting material -- it is -- this, when the main front face of the 2nd dielectric substrate is made to counter the main front face of said 1st dielectric substrate The 2nd pad with which this 2nd pad is arranged in said 1st pad and a corresponding location, It is arranged on the main front face of said 2nd dielectric substrate, and is formed with an oxide superconducting material. Superconducting circuit equipment according to claim 1 or 2 through which had two or more wiring connected to said 2nd pad, and pasted up on the top face of said 1st pad with which each top face of said 2nd pad corresponds, and both have flowed electrically.
[Claim 4] The process which forms the 1st oxide superconduction film on the main front face of the 1st dielectric substrate, The process which leaves two or more 1st pads which carry out patterning of said 1st oxide superconduction film, and are distributed discretely, The process which forms the touch-down electric conduction film which consists of an oxide superconducting material on some fields on the front face of main of said 1st dielectric substrate, The manufacture approach of superconducting circuit equipment of having the process which forms a dielectric thin film on the front face of said touch-down electric conduction film, and the process which forms the superconducting circuit pattern which consisted of an oxide superconducting material and was connected to said 1st pad on the front face of said dielectric thin film.
[Claim 5] The manufacture approach of superconducting circuit equipment according to claim 4 with the larger height of said 1st pad than the thickness of the sum total of said touch-down electric conduction film, dielectric thin film, and superconducting circuit pattern.
[Claim 6] The process which forms said touch-down electric conduction film so that said the 1st main front face and said 1st pad of a dielectric substrate may be covered So that 1st at least one pad may be electrically separated from other 1st pad the process which forms the 2nd oxide superconducting thin film, and among said 1st pad And the manufacture approach of superconducting circuit equipment including the process which carries out patterning of said 2nd

oxide superconducting thin film so that said 2nd oxide superconducting thin film may remain on some fields on the front face of main of said 1st dielectric substrate according to claim 4 or 5.
[Claim 7] furthermore, two or more 2nd pads formed with the oxide superconducting material on the main front face -- it is -- this, when the main front face of the 2nd dielectric substrate is made to counter the main front face of said 1st dielectric substrate The 2nd pad with which this 2nd pad is arranged in said 1st pad and a corresponding location, The process for which the 2nd dielectric substrate which has two or more wiring which was formed with the oxide superconducting material and connected to said 2nd pad is prepared, The process which arranges said 1st dielectric substrate and said 2nd dielectric substrate so that the top face of said 1st pad with which both main front faces are made to counter, and each top face of said 2nd pad corresponds may be contacted, The manufacture approach of superconducting circuit equipment including the process which heats said 1st dielectric substrate and said 2nd dielectric substrate, and pastes up said 1st pad and the 2nd pad corresponding to it according to claim 4 to 6.
[Claim 8] It is the compound substrate with which the main front face was formed with dielectric materials, and the interface of dielectric materials and an oxide superconducting material was caudad formed rather than the main front face. The 1st field and the 2nd field which adjoins at it are demarcated in the main front face of this substrate, and it sets to this 1st field. The depth from the main front face to said interface is about 1 law, and it sets to this 2nd field. Said compound substrate with which the depth from the main front face to said interface is deep as it separates from said 1st field, The superconducting circuit pattern formed on the 1st [in the main front face of said compound substrate / said] field, It is the drawer pattern which is formed on the 2nd [in the main front face of said compound substrate / said] field, and consists of a superconducting material. This drawer pattern is superconducting circuit equipment which has said drawer pattern which is becoming thick gradually as it extends in the direction which intersects the boundary line of said 1st field and 2nd field, it connects with said superconducting circuit pattern and it separates from said 1st field.
[Claim 9] The 1st member which has the slant face where said compound substrate follows the top face parallel to the main front face and this top face of this compound substrate, and was formed with the oxide superconducting material, The 2nd member which has the slant face stuck to the slant face of said 1st member, and the top face which demarcates one virtual flat surface with the top face of said 1st member, and was formed with dielectric materials, Superconducting circuit equipment containing the dielectric thin film which covers the top face of said 1st member, and the top face of said 2nd member according to claim 8.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the equipment which has the electronic circuitry which used the superconducting material.
[0002]
[Description of the Prior Art] If a superconducting material is used for electric wiring, surface electrical resistance to the high frequency current can be made low. Moreover, if the tunnel effect component of superconduction is used, reduction of power consumption and improvement in the speed of operation will be attained. Since a superconducting material has these outstanding properties, application of the superconducting material to a RF circuit is advanced. The attempt which uses an oxide superconducting material for wiring has been made since the discovery of an oxide superconducting material whose superconduction transition temperature exceeds liquefaction nitrogen temperature.
[0003] In a RF circuit, in order to make a signal spread efficiently, generally microstrip line structure is adopted. The ingredient excellent in dielectric characteristics (tandelta) fits the dielectric layer of microstrip line structure. Moreover, it is desirable that epitaxial growth of the oxide superconducting thin film can be carried out on a dielectric layer. For these reasons, MgO is used as a dielectric layer of microstrip line structure using an oxide superconducting material in many cases.
[0004]
[Problem(s) to be Solved by the Invention] If the characteristic impedance of wiring is changed spatially, reflection of a signal will arise at the changing point of a characteristic impedance, and attenuation of a signal and a wave-like distortion will arise. If the frequency of a signal becomes high, attenuation and waveform distortion of a signal will become remarkable.
[0005] The characteristic impedance of microstrip line structure is determined by a dielectric constant, its thickness, wiring width of face, etc. of a dielectric layer in approximation. In order to set a characteristic impedance as about 50ohms, using MgO as a dielectric layer, dielectric layer thickness and wiring width of face must be made comparable.
[0006] A thin film multilayering technique is used for production of a superconduction integrated circuit device. In this case, the thickness of a thin film is usually set as 1 micrometer or less from the irregularity on the front face of a thin film, crystallinity, growth time amount, etc. When the dielectric layer thickness which consists of MgO is 1 micrometer or less, in order to set the characteristic impedance of a microstrip line to 50 ohms, it is necessary to set wiring width of face to 1 micrometer or less.
[0007] On the other hand, external wiring connected to an integrated circuit device has coaxial structure, and even if the size of the central conductor is thin, it is about 0.1mm. The big difference with the wiring width of face of an integrated circuit device and the size of the central conductor of a coaxial cable makes an assembly difficult, and enlarges reflection by the impedance mismatch.
[0008] Moreover, when using the superconducting material of a metal system, flip chip bonding is used for connection between an integrated-circuit substrate and a mounting substrate. However,

when using an oxide superconducting material, it is difficult to perform flip chip bonding, and the connection method through a usual state electrical conduction wire has been adopted. If a usual state electrical conduction wire is used, a transmission characteristic will deteriorate compared with the case where direct continuation of the superconducting materials is carried out.
[0009] The purpose of this invention is offering the superconducting circuit equipment which can mount a superconducting circuit substrate on a mounting substrate, and its manufacture approach, without using a usual state electrical conduction wire.
[0010] Other purposes of this invention are offering the superconducting circuit equipment which can aim at adjustment of the characteristic impedance of superconducting circuit equipment and an external track.
[0011]
[Means for Solving the Problem] Two or more 1st pads which according to one viewpoint of this invention have been arranged discretely and formed with the oxide superconducting material on the main front face of the 1st dielectric substrate and said 1st dielectric substrate, The touch-down electric conduction film which has been arranged on the main front face of said 1st dielectric substrate, and was formed with the oxide superconducting material, The front face of said touch-down electric conduction film is arranged on the front face of a wrap dielectric film and said dielectric film. It is formed with an oxide superconducting material, and has the superconducting circuit pattern connected to said 1st pad, and superconducting circuit equipment with the sum total of the thickness of said touch-down electric conduction film, said dielectric film, and said superconducting circuit pattern smaller than the height of said 1st pad is offered.
[0012] Since the 1st pad is comparatively expensive, even if curvature is in the 1st dielectric substrate and the mounting substrate for mounting it, it is stabilized and the 1st pad and the pad by the side of a mounting substrate can be pasted up.
[0013] The process which forms the 1st oxide superconduction film on the main front face of the 1st dielectric substrate according to other viewpoints of this invention, The process which leaves two or more 1st pads which carry out patterning of said 1st oxide superconduction film, and are distributed discretely, The process which forms the touch-down electric conduction film which consists of an oxide superconducting material on some fields on the front face of main of said 1st dielectric substrate, The manufacture approach of superconducting circuit equipment of having the process which forms a dielectric thin film on the front face of said touch-down electric conduction film, and the process which forms the superconducting circuit pattern which consisted of an oxide superconducting material on the front face of said dielectric thin film, and was connected to said 1st pad is offered.
[0014] The 1st pad is formed at a different process from the process which forms a superconducting circuit pattern. For this reason, it becomes possible to set up the height of the 1st pad independently with the thickness of a superconducting circuit pattern. If the 1st pad is made high, it will be hard coming to win popularity the effect of the curvature of a substrate etc.
[0015] According to other viewpoints of this invention, it is the compound substrate with which the main front face was formed with dielectric materials, and the interface of dielectric materials and an oxide superconducting material was caudad formed rather than the main front face. The 1st field and the 2nd field which adjoins at it are demarcated in the main front face of this substrate, and it sets to this 1st field. The depth from the main front face to said interface is about 1 law, and it sets to this 2nd field. Said compound substrate with which the depth from the main front face to said interface is deep as it separates from said 1st field, The superconducting circuit pattern formed on the 1st [in the main front face of said compound substrate / said] field, It is the drawer pattern which is formed on the 2nd [in the main front face of said compound substrate / said] field, and consists of a superconducting material. This drawer pattern extends in the direction which intersects the boundary line of said 1st field and 2nd field, and is connected to said superconducting circuit pattern, and the superconducting circuit equipment which has said drawer pattern which is becoming thick gradually is offered as it separates from said 1st field.
[0016] This superconducting circuit equipment has the microstrip line structure which makes the

interface of the dielectric materials of a compound substrate, and a superconducting material a touch-down conductor side. The drawer pattern is thick as spacing of a drawer pattern and a touch-down conductor side becomes large. For this reason, spatial fluctuation of the characteristic impedance of a drawer pattern can be lessened. Lead wire, such as a RF connector, can be easily pasted up on the thick part of a drawer pattern.

[0017]

[Embodiment of the Invention] With reference to drawing 1 - drawing 4 , the superconducting circuit equipment by the 1st example of this invention is explained.

[0018] Drawing 1 (A) shows the outline sectional view of the superconducting circuit equipment by the 1st example, and drawing 1 (B) shows a top view. The sectional view in alternate long and short dash line A1-A1 of drawing 1 (B) is equivalent to drawing 1 (A). Superconducting circuit equipment is fundamentally constituted including the superconducting circuit substrate 1 and the mounting substrate 50. The superconducting circuit substrate 1 is constituted including two or more 1st pads 10 which consist of a dielectric substrate 5 which consists of MgO, and YBa2Cu3O7-d (YBCO). d is the amount of deficits of oxygen here. Two or more 1st pads 10 are discretely distributed on the main front face of the dielectric substrate 5. About the more detailed configuration of the superconducting circuit substrate 1, it mentions later with reference to drawing 2 and drawing 3 .

[0019] The mounting substrate 50 is constituted including two or more 2nd pads 55, wiring 56, and the pad 57 for external connection which serve as the dielectric substrate 51 which consists of MgO from YBCO formed on the main front face. The 2nd pad 55 is arranged in the location corresponding to the 1st pad 10, when those main front faces are made to counter and the dielectric substrates 5 and 51 have been arranged. The 2nd pad 55 is electrically connected to the pad 57 for external connection through wiring 56, respectively.

[0020] Each top face of the 1st pad 10 has pasted the top face of the 2nd pad 55 corresponding to the 1st pad 10 concerned. Adhesion of pads contacts both and is performed by heating at 920 degrees C in an oxygen ambient atmosphere for 2 hours. 920 degrees C is the sintering temperature of YBCO. In addition, whenever [stoving temperature] can be lowered by pressurizing pads. For example, when it pressurized using a stainless steel spring, both pasted up at the temperature of 900 degrees C.

[0021] The central conductor 60 of a RF connector is stuck to the pad 57 for external connection by pressure. In addition, the outer conductor of a RF connector is connected to the grand side of the circuit pattern of the mounting substrate 50. The external signal line is connected to a RF connector. As the external signal line, a coaxial cable is usually used.

[0022] Next, with reference to drawing 2 and drawing 3 , the manufacture approach of the superconducting circuit substrate 1 is explained.

[0023] As shown in drawing 2 (A), the dielectric substrate 5 which consists of MgO is prepared. On the main front face of the dielectric substrate 5, the superconduction thick film 6 with a thickness of 10 micrometers it is thin from YBCO is formed. Formation of the superconduction thick film 6 is performed by liquid phase crystal growth (LPE). a MgO substrate top -- the YBCO film -- LPE -- the approach of forming using law is explained to JP,7-33590,A at the detail. Hereafter, the formation approach of the superconduction thick film 6 is explained briefly.

[0024] First, the YBCO film with a thickness of 0.01-1 micrometer is grown up with plasma vacuum deposition on the main front face of the dielectric substrate 5. the YBCO film top formed by plasma vacuum deposition -- LPE -- the thick YBCO film is grown up using law. The mixed melt of BaO and CuO is used as a solvent. The mole ratio of Ba and Cu is 3:5. Y2B aCuO5 is used as solute feed materials. The crucible into which the solute and the solvent were put is heated and melting of the solvent is carried out to a solute. Then, skin temperature is adjusted to 1000 degrees C, and a crucible pars basilaris ossis occipitalis is adjusted to 1010 degrees C. In this condition, solute feed materials have precipitated in the lower part of the solvent of a liquid condition. Solute feed materials are dissolving into a solvent.

[0025] The front face of the YBCO film formed in this solution with plasma vacuum deposition is contacted, and a YBCO thick film is grown up by considering a rotational frequency as per minute 100 rotation. The YBCO film formed with plasma vacuum deposition serves as seed

crystal. A YBCO thick film is grown up so that the thickness of the YBCO thick film after growth may become a little thicker than 10 micrometers. The front face of a YBCO thick film is ground after growth, and the superconduction thick film 6 with a thickness of 10 micrometers is formed.
[0026] As shown in drawing 2 (B), patterning of the superconduction thick film 6 is carried out, and it leaves two or more pads 10. A pad 10 is discretely distributed on the main front face of the dielectric substrate 5. The wet etching which used the nitric acid performs patterning of the superconduction thick film 6. The diameter of each pad 10 is about 0.5mm.
[0027] As shown in drawing 2 (C), the superconducting thin film 12 with a thickness of 0.2-0.3 micrometers it is thin from YBCO is formed so that the main front face of the dielectric substrate 5 and the front face of a pad 10 may be covered. For example, laser vacuum evaporationo performs formation of a superconducting thin film 12.
[0028] As shown in drawing 2 (D), patterning of the superconducting thin film 12 is carried out. Touch-down electric conduction film 12a remains on the field where the pad 10 on the front face of main of the dielectric substrate 5 is not arranged. Superconducting thin film 12b remains also on each front face of a pad 10. Touch-down electric conduction film 12a follows wrap superconducting thin film 12b in at least one pad 10. Moreover, at least one pad 10 is electrically separated from touch-down electric conduction film 12a. In drawing 2 (B), wrap superconducting thin film 12b follows touch-down electric conduction film 12a in the right-hand side pad 10, and the left-hand side pad 10 is electrically separated from touch-down electric conduction film 12a.

[0029] As shown in drawing 3 (E), the dielectric thin film 13 with a thickness of 0.2-0.3 micrometers it is thin from MgO is formed on a substrate. For example, laser vacuum evaporationo or sputtering can perform formation of the dielectric thin film 13.
[0030] As shown in drawing 3 (F), the wrap dielectric thin film 13 is removed for a pad 10. Wrap dielectric thin film 13a remains touch-down electric conduction film 12a. Partial removal of the dielectric thin film 13 can be performed by covering the part which it should leave with a resist pattern, and carrying out ion milling of the exposed part.
[0031] As shown in drawing 3 (G), while forming superconducting circuit pattern 15a which consists of YBCO on the front face of dielectric thin film 13a, the laminating of the superconducting thin film 15b which consists a pad 10 of YBCO further on wrap superconducting thin film 12b is carried out. Superconducting circuit pattern 15a and superconducting thin film 15b are formed by carrying out patterning of this YBCO thin film, after growing up a YBCO thin film on a substrate. The thickness of superconducting circuit pattern 15a and superconducting thin film 15b is 0.2-0.3 micrometers.
[0032] The superconducting circuit substrate 1 of microstrip line structure is produced through the process from drawing 2 (A) to drawing 3 (G). A logical circuit is mentioned as an example of a superconducting circuit. The example of 1 configuration of a comparator circuit is an IEEE transaction. ON Applied It is indicated by 2987-2992 pages of volume [7th] No. 2 (June, 1997) (IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL.7, NO.2, JUNE 1997) of super KONDAKUTIBITI.
[0033] The mounting substrate 50 shown in drawing 1 (A) is produced by forming a superconduction pattern on the front face of the dielectric substrate 51 by the same approach as formation of superconducting circuit pattern 15a explained by drawing 3 (G), and superconducting thin film 15b. The height of the pad 55 by the side of the mounting substrate 50 is comparable as the thickness of wiring 56, and good.
[0034] Drawing 4 shows the temperature dependence of resistance between the pad 10 of drawing 1 (A), and a pad 55. An axis of abscissa expresses temperature with a unit "K", and an axis of ordinate expresses resistance with a unit "omega." Measurement of resistance was performed using 4 terminal method. In abbreviation 90K or less range which is the superconduction transition temperature of YBCO, it turns out that resistance is very low. By making YBCO into a superconductive state, it is possible to connect the superconducting circuit pattern on a superconducting circuit substrate and wiring on a mounting substrate by low resistance.
[0035] In addition, judging from a current potential property, it will not be in a perfect

superconductive state between a pad 10 and a pad 55, but it is thought that slight residual resistance remains. However, residual resistance of this level hardly affects actuation of a RF circuit. As a cause by which residual resistance remains, resistance resulting from the grain boundary of the interface between pads can be considered. It is thought that this resistance can be decreased by optimizing both surface treatment before contact of a pad.

[0036] Since the height of a pad 10 is about 10 micrometers, even when curvature is in the dielectric substrate 5 and the dielectric substrate 51 by the side of the mounting substrate 50, it is stabilized with sufficient repeatability and the superconducting circuit substrate 1 can be pasted up on the mounting substrate 50. Moreover, if a pad 10 is too thin, the superconducting material which forms a pad with heating at the time of adhesion is spread in a substrate, and mechanical and electric adhesion may not be obtained.

[0037] According to the experiment of artificers, good adhesion was not obtained when the height of a pad 10 was lower than 0.4 micrometers. Probably, it will be desirable to set the height of a pad 10 to 0.4 micrometers or more. Moreover, it is more desirable than the thickness of the sum total of touch-down electric conduction film 12a, dielectric thin film 13a, and superconducting circuit pattern 15a to make a pad 10 high. In addition, in order to secure sufficient adhesion, it is more desirable to set the height of a pad 10 to 1 micrometers or more.

[0038] Although drawing 1 explained the case where one superconducting circuit substrate was mounted on one mounting substrate, two or more superconducting circuit substrates may be mounted on one mounting substrate.

[0039] Drawing 5 shows the outline top view of the superconducting circuit equipment which mounted two or more superconducting circuit substrates on one mounting substrate. On the main front face of the mounting substrate 50, two or more superconducting circuit substrates 1 are mounted. Both adhesion is performed by the same approach as the adhesion in the case of the superconducting circuit equipment shown in drawing 1 (A).

[0040] On the field near [on the front face of main of the dielectric substrate 51 which constitutes the mounting substrate 50] the periphery section, two or more pads 57 for external connection are arranged. The pad 57 for external connection is connected to the pad for connection with the superconducting circuit substrate 1 by wiring 56. Wiring 58 connects the pads for connection with the superconducting circuit substrate 1.

[0041] Thus, improvement in packaging density can be aimed at by mounting two or more superconducting circuit substrates on one mounting substrate.

[0042] Next, with reference to drawing 6 , the superconducting circuit equipment by the 2nd example of this invention is explained.

[0043] Drawing 6 (A) shows the sectional view of the superconducting circuit equipment by the 2nd example, and drawing 6 (B) shows the top view. The sectional view in alternate long and short dash line A6-A6 of drawing 6 (B) is equivalent to the sectional view of drawing 6 (A).

[0044] The compound substrate 60 is constituted including the superconduction member 61 and two dielectric members 62. The superconduction member 61 is a plate with which a cross section consists of YBCO with a thickness of 0.3mm of trapezoidal shape. That is, the superconduction member 61 has the slant face which connects a top face and an inferior surface of tongue parallel to mutual, and a top face and an inferior surface of tongue. The angle of a base and a slant face to make is 45 degrees. Let the superconduction member 61 be crystal-face bearing where the c-axis becomes a top face and a perpendicular. If this crystal-face bearing is adopted, the invasion length of a magnetic field becomes short and can aim at the fall of the inductance of wiring.

[0045] Each of the dielectric member 62 is a plate which consists of MgO, and has the slant face which connects a top face and an inferior surface of tongue parallel to mutual, and a top face and an inferior surface of tongue. The slant face of two dielectric members 62 is pasted up on two slant faces of the superconduction member 61 through the superconducting thin film 64 which consists of YBCO, respectively. The top face of the dielectric member 62 demarcates one virtual flat surface with the top face of the superconduction member 61. That is, one flat top face is demarcated by the superconduction member 61 and the dielectric member 62. On the inferior surface of tongue of the dielectric member 62, the superconducting thin film 63 which

consists of YBCO is formed. The front face of a superconducting thin film 63 demarcates one virtual flat surface with the inferior surface of tongue of the superconduction member 61.
[0046] On the top face of the superconduction member 61 and the dielectric member 62, the dielectric thin film 65 with a thickness of 0.3 micrometers it is thin from MgO is formed. The front face of the compound substrate 60 is classified into the 1st field 75 corresponding to the top face of the superconduction member 61, the 2nd field 76 corresponding to a slant face, and the 3rd field 77 corresponding to the inferior surface of tongue of the dielectric member 62.
[0047] On the 1st field 75 of the front face of the compound substrate 60, with a thickness of 0.3 micrometers it is thin from YBCO superconducting circuit pattern 70A is formed. Superconducting circuit pattern 70A is a delay circuit, a multistage filter, a logical circuit, etc. On the 2nd and 3rd fields 76 and 77, with a thickness of 0.3 micrometers it is thin from YBCO drawer pattern 70B is formed. Drawer pattern 70B is connected to superconducting circuit pattern 70A. The width of face of the part arranged in the 2nd field 76 among drawer pattern 70B is thick as it separates from the 1st field 75.
[0048] The pattern width of face of superconducting circuit pattern 70A is 0.3 micrometers. The width of face of the part on the boundary of the 1st field 75 and the 2nd field 76 is 0.3 micrometers among drawer pattern 70B, and the width of face of the part on the boundary of the 2nd field 76 and the 3rd field 77 and the part in the 3rd field 77 is 0.3mm.
[0049] The compound substrate 60 is contained in the copper cavity 72. The superconduction member 61 and a superconducting thin film 63 are electrically connected to the inside of a cavity 72. The central conductor 71 of a high frequency connector is inserted into a cavity 72 via the through tube prepared in the cavity 72, and is stuck to drawer pattern 70B by pressure. The outer conductor of a high frequency connector is connected to a cavity 72.
[0050] the top face of the superconduction member 61, and superconducting thin films 63 and 64 -- touch-down -- the microstrip line structure used as a conductor is acquired. the touch-down from the main front face of the compound substrate 60, i.e., the front face of the dielectric thin film 65, -- the depth to a conductor is fixed in the 1st field 75. In the 2nd field 76, this depth is deep as it separates from the 1st field 75.
[0051] drawer pattern 70B -- the touch-down from the main front face of the compound substrate 60 -- the depth to a conductor becomes deep -- it is alike, and it follows and is thick according to the depth. For this reason, it becomes possible to make the characteristic impedance of a drawer pattern regularity mostly spatially. Since drawer pattern 70B is made large into the 3rd field 77, it can stick easily drawer pattern 70B and a central conductor 71 by pressure. Since the touch area of drawer pattern 70B and a central conductor 71 becomes large, both contact resistance can be reduced. Moreover, since the impedance of a connection has consistency, the reflection loss of a RF signal can be reduced.
[0052] Next, the manufacture approach of the superconducting circuit equipment by the 2nd example is explained. The superconduction member 61 and the dielectric member 62 are obtained by grinding aslant the edge of the single crystal substrate of YBCO, and the single crystal substrate of MgO, or cutting off aslant, respectively. Superconducting thin films 63 and 64 are formed of laser vacuum evaporationo or sputtering.
[0053] Adhesion with the dielectric member 62 and the superconduction member 61 in which superconducting thin films 63 and 64 were formed is performed by contacting both slant faces and overheating at about 920 degrees C.
[0054] Laser vacuum evaporationo can perform formation of the dielectric thin film 65. For example, laser vacuum evaporationo is performed on condition that the temperature of 740 degrees C, and pressure 200mTorr in an oxygen ambient atmosphere. Superconducting circuit pattern 70A and drawer pattern 70B are formed by carrying out patterning of this YBCO thin film, after forming a YBCO thin film. Laser vacuum evaporationo performs formation of a YBCO thin film. The condition is the same as that of the case of formation of the dielectric thin film 65.

[0055] In the above-mentioned example, although MgO was used as dielectric materials, using YBCO as a superconducting material, other oxide superconducting materials and dielectric materials may be used. As an usable oxide superconducting material, the oxide superconducting

material which used Nd, Eu, Ho, etc. instead of Y of YBCO is mentioned. Other than MgO, strontium titanate (STO), La0.35Sr0.65aluminum0.675Ta 0.325O3 (LAST), etc. are mentioned.

[0056] Although this invention was explained in accordance with the example above, this invention is not restricted to these. For example, probably, it will be obvious to this contractor for various modification, amelioration, combination, etc. to be possible.

[0057]

[Effect of the Invention] As explained above, according to this invention, a superconducting circuit substrate can be pasted up with sufficient repeatability on a mounting substrate by making the pad of a superconducting circuit substrate high. wiring and touch-down of microstrip line structure -- even if it changes wiring width of face by changing distance with a conductor, the characteristic impedance can be kept constant. By making thick wiring width of face of a connection with the exterior, it becomes possible to perform adhesion with wiring and an external conductor easily.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the equipment which has the electronic circuitry which used the superconducting material.

[Translation done.]

PRIOR ART

[Description of the Prior Art] If a superconducting material is used for electric wiring, surface electrical resistance to the high frequency current can be made low. Moreover, if the tunnel effect component of superconduction is used, reduction of power consumption and improvement in the speed of operation will be attained. Since a superconducting material has these outstanding properties, application of the superconducting material to a RF circuit is advanced. The attempt which uses an oxide superconducting material for wiring has been made since the discovery of an oxide superconducting material whose superconduction transition temperature exceeds liquefaction nitrogen temperature.
[0003] In a RF circuit, in order to make a signal spread efficiently, generally microstrip line structure is adopted. The ingredient excellent in dielectric characteristics (tandelta) fits the dielectric layer of microstrip line structure. Moreover, it is desirable that epitaxial growth of the oxide superconducting thin film can be carried out on a dielectric layer. For these reasons, MgO is used as a dielectric layer of microstrip line structure using an oxide superconducting material in many cases.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, according to this invention, a superconducting circuit substrate can be pasted up with sufficient repeatability on a mounting substrate by making the pad of a superconducting circuit substrate high. wiring and touch-down of microstrip line structure -- even if it changes wiring width of face by changing distance with a conductor, the characteristic impedance can be kept constant. By making thick wiring width of face of a connection with the exterior, it becomes possible to perform adhesion with wiring and an external conductor easily.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] If the characteristic impedance of wiring is changed spatially, reflection of a signal will arise at the changing point of a characteristic impedance, and attenuation of a signal and a wave-like distortion will arise. If the frequency of a signal becomes high, attenuation and waveform distortion of a signal will become remarkable.
[0005] The characteristic impedance of microstrip line structure is determined by a dielectric constant, its thickness, wiring width of face, etc. of a dielectric layer in approximation. In order to set a characteristic impedance as about 50ohms, using MgO as a dielectric layer, dielectric layer thickness and wiring width of face must be made comparable.
[0006] A thin film multilayering technique is used for production of a superconduction integrated circuit device. In this case, the thickness of a thin film is usually set as 1 micrometer or less from the irregularity on the front face of a thin film, crystallinity, growth time amount, etc. When the dielectric layer thickness which consists of MgO is 1 micrometer or less, in order to set the characteristic impedance of a microstrip line to 50 ohms, it is necessary to set wiring width of face to 1 micrometer or less.
[0007] On the other hand, external wiring connected to an integrated circuit device has coaxial structure, and even if the size of the central conductor is thin, it is about 0.1mm. The big difference with the wiring width of face of an integrated circuit device and the size of the central conductor of a coaxial cable makes an assembly difficult, and enlarges reflection by the impedance mismatch.
[0008] Moreover, when using the superconducting material of a metal system, flip chip bonding is used for connection between an integrated-circuit substrate and a mounting substrate. However, when using an oxide superconducting material, it is difficult to perform flip chip bonding, and the connection method through a usual state electrical conduction wire has been adopted. If a usual state electrical conduction wire is used, a transmission characteristic will deteriorate compared with the case where direct continuation of the superconducting materials is carried out.
[0009] The purpose of this invention is offering the superconducting circuit equipment which can mount a superconducting circuit substrate on a mounting substrate, and its manufacture approach, without using a usual state electrical conduction wire.
[0010] Other purposes of this invention are offering the superconducting circuit equipment which can aim at adjustment of the characteristic impedance of superconducting circuit equipment and an external track.

[Translation done.]

MEANS

[Means for Solving the Problem] Two or more 1st pads which according to one viewpoint of this invention have been arranged discretely and formed with the oxide superconducting material on the main front face of the 1st dielectric substrate and said 1st dielectric substrate, The touch-down electric conduction film which has been arranged on the main front face of said 1st dielectric substrate, and was formed with the oxide superconducting material, The front face of said touch-down electric conduction film is arranged on the front face of a wrap dielectric film and said dielectric film. It is formed with an oxide superconducting material, and has the superconducting circuit pattern connected to said 1st pad, and superconducting circuit equipment with the sum total of the thickness of said touch-down electric conduction film, said dielectric film, and said superconducting circuit pattern smaller than the height of said 1st pad is offered.
[0012] Since the 1st pad is comparatively expensive, even if curvature is in the 1st dielectric substrate and the mounting substrate for mounting it, it is stabilized and the 1st pad and the pad by the side of a mounting substrate can be pasted up.
[0013] The process which forms the 1st oxide superconduction film on the main front face of the 1st dielectric substrate according to other viewpoints of this invention, The process which leaves two or more 1st pads which carry out patterning of said 1st oxide superconduction film, and are distributed discretely, The process which forms the touch-down electric conduction film which consists of an oxide superconducting material on some fields on the front face of main of said 1st dielectric substrate, The manufacture approach of superconducting circuit equipment of having the process which forms a dielectric thin film on the front face of said touch-down electric conduction film, and the process which forms the superconducting circuit pattern which consisted of an oxide superconducting material on the front face of said dielectric thin film, and was connected to said 1st pad is offered.
[0014] The 1st pad is formed at a different process from the process which forms a superconducting circuit pattern. For this reason, it becomes possible to set up the height of the 1st pad independently with the thickness of a superconducting circuit pattern. If the 1st pad is made high, it will be hard coming to win popularity the effect of the curvature of a substrate etc.
[0015] According to other viewpoints of this invention, it is the compound substrate with which the main front face was formed with dielectric materials, and the interface of dielectric materials and an oxide superconducting material was caudad formed rather than the main front face. The 1st field and the 2nd field which adjoins at it are demarcated in the main front face of this substrate, and it sets to this 1st field. The depth from the main front face to said interface is about 1 law, and it sets to this 2nd field. Said compound substrate with which the depth from the main front face to said interface is deep as it separates from said 1st field, The superconducting circuit pattern formed on the 1st [in the main front face of said compound substrate / said] field, It is the drawer pattern which is formed on the 2nd [in the main front face of said compound substrate / said] field, and consists of a superconducting material. This drawer pattern extends in the direction which intersects the boundary line of said 1st field and 2nd field, and is connected to said superconducting circuit pattern, and the superconducting circuit equipment which has said drawer pattern which is becoming thick gradually is offered as it

separates from said 1st field.
[0016] This superconducting circuit equipment has the microstrip line structure which makes the interface of the dielectric materials of a compound substrate, and a superconducting material a touch-down conductor side. The drawer pattern is thick as spacing of a drawer pattern and a touch-down conductor side becomes large. For this reason, spatial fluctuation of the characteristic impedance of a drawer pattern can be lessened. Lead wire, such as a RF connector, can be easily pasted up on the thick part of a drawer pattern.
[0017]
[Embodiment of the Invention] With reference to drawing 1 - drawing 4 , the superconducting circuit equipment by the 1st example of this invention is explained.
[0018] Drawing 1 (A) shows the outline sectional view of the superconducting circuit equipment by the 1st example, and drawing 1 (B) shows a top view. The sectional view in alternate long and short dash line A1-A1 of drawing 1 (B) is equivalent to drawing 1 (A). Superconducting circuit equipment is fundamentally constituted including the superconducting circuit substrate 1 and the mounting substrate 50. The superconducting circuit substrate 1 is constituted including two or more 1st pads 10 which consist of a dielectric substrate 5 which consists of MgO, and YBa2Cu3O7-d (YBCO). d is the amount of deficits of oxygen here. Two or more 1st pads 10 are discretely distributed on the main front face of the dielectric substrate 5. About the more detailed configuration of the superconducting circuit substrate 1, it mentions later with reference to drawing 2 and drawing 3 .
[0019] The mounting substrate 50 is constituted including two or more 2nd pads 55, wiring 56, and the pad 57 for external connection which serve as the dielectric substrate 51 which consists of MgO from YBCO formed on the main front face. The 2nd pad 55 is arranged in the location corresponding to the 1st pad 10, when those main front faces are made to counter and the dielectric substrates 5 and 51 have been arranged. The 2nd pad 55 is electrically connected to the pad 57 for external connection through wiring 56, respectively.
[0020] Each top face of the 1st pad 10 has pasted the top face of the 2nd pad 55 corresponding to the 1st pad 10 concerned. Adhesion of pads contacts both and is performed by heating at 920 degrees C in an oxygen ambient atmosphere for 2 hours. 920 degrees C is the sintering temperature of YBCO. In addition, whenever [stoving temperature] can be lowered by pressurizing pads. For example, when it pressurized using a stainless steel spring, both pasted up at the temperature of 900 degrees C.
[0021] The central conductor 60 of a RF connector is stuck to the pad 57 for external connection by pressure. In addition, the outer conductor of a RF connector is connected to the grand side of the circuit pattern of the mounting substrate 50. The external signal line is connected to a RF connector. As the external signal line, a coaxial cable is usually used.
[0022] Next, with reference to drawing 2 and drawing 3 , the manufacture approach of the superconducting circuit substrate 1 is explained.
[0023] As shown in drawing 2 (A), the dielectric substrate 5 which consists of MgO is prepared. On the main front face of the dielectric substrate 5, the superconduction thick film 6 with a thickness of 10 micrometers it is thin from YBCO is formed. Formation of the superconduction thick film 6 is performed by liquid phase crystal growth (LPE). a MgO substrate top -- the YBCO film -- LPE -- the approach of forming using law is explained to JP,7-33590,A at the detail. Hereafter, the formation approach of the superconduction thick film 6 is explained briefly.
[0024] First, the YBCO film with a thickness of 0.01-1 micrometer is grown up with plasma vacuum deposition on the main front face of the dielectric substrate 5. the YBCO film top formed by plasma vacuum deposition -- LPE -- the thick YBCO film is grown up using law. The mixed melt of BaO and CuO is used as a solvent. The mole ratio of Ba and Cu is 3:5. Y2B aCuO5 is used as solute feed materials. The crucible into which the solute and the solvent were put is heated and melting of the solvent is carried out to a solute. Then, skin temperature is adjusted to 1000 degrees C, and a crucible pars basilaris ossis occipitalis is adjusted to 1010 degrees C. In this condition, solute feed materials have precipitated in the lower part of the solvent of a liquid condition. Solute feed materials are dissolving into a solvent.
[0025] The front face of the YBCO film formed in this solution with plasma vacuum deposition is

contacted, and a YBCO thick film is grown up by considering a rotational frequency as per minute 100 rotation. The YBCO film formed with plasma vacuum deposition serves as seed crystal. A YBCO thick film is grown up so that the thickness of the YBCO thick film after growth may become a little thicker than 10 micrometers. The front face of a YBCO thick film is ground after growth, and the superconduction thick film 6 with a thickness of 10 micrometers is formed.
[0026] As shown in drawing 2 (B), patterning of the superconduction thick film 6 is carried out, and it leaves two or more pads 10. A pad 10 is discretely distributed on the main front face of the dielectric substrate 5. The wet etching which used the nitric acid performs patterning of the superconduction thick film 6. The diameter of each pad 10 is about 0.5mm.
[0027] As shown in drawing 2 (C), the superconducting thin film 12 with a thickness of 0.2-0.3 micrometers it is thin from YBCO is formed so that the main front face of the dielectric substrate 5 and the front face of a pad 10 may be covered. For example, laser vacuum evaporationo performs formation of a superconducting thin film 12.
[0028] As shown in drawing 2 (D), patterning of the superconducting thin film 12 is carried out. Touch-down electric conduction film 12a remains on the field where the pad 10 on the front face of main of the dielectric substrate 5 is not arranged. Superconducting thin film 12b remains also on each front face of a pad 10. Touch-down electric conduction film 12a follows wrap superconducting thin film 12b in at least one pad 10. Moreover, at least one pad 10 is electrically separated from touch-down electric conduction film 12a. In drawing 2 (B), wrap superconducting thin film 12b follows touch-down electric conduction film 12a in the right-hand side pad 10, and the left-hand side pad 10 is electrically separated from touch-down electric conduction film 12a.

[0029] As shown in drawing 3 (E), the dielectric thin film 13 with a thickness of 0.2-0.3 micrometers it is thin from MgO is formed on a substrate. For example, laser vacuum evaporationo or sputtering can perform formation of the dielectric thin film 13.
[0030] As shown in drawing 3 (F), the wrap dielectric thin film 13 is removed for a pad 10. Wrap dielectric thin film 13a remains touch-down electric conduction film 12a. Partial removal of the dielectric thin film 13 can be performed by covering the part which it should leave with a resist pattern, and carrying out ion milling of the exposed part.
[0031] As shown in drawing 3 (G), while forming superconducting circuit pattern 15a which consists of YBCO on the front face of dielectric thin film 13a, the laminating of the superconducting thin film 15b which consists a pad 10 of YBCO further on wrap superconducting thin film 12b is carried out. Superconducting circuit pattern 15a and superconducting thin film 15b are formed by carrying out patterning of this YBCO thin film, after growing up a YBCO thin film on a substrate. The thickness of superconducting circuit pattern 15a and superconducting thin film 15b is 0.2-0.3 micrometers.
[0032] The superconducting circuit substrate 1 of microstrip line structure is produced through the process from drawing 2 (A) to drawing 3 (G). A logical circuit is mentioned as an example of a superconducting circuit. The example of 1 configuration of a comparator circuit is an IEEE transaction. ON Applied It is indicated by 2987-2992 pages of volume [7th] No. 2 (June, 1997) (IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL.7, NO.2, JUNE 1997) of super KONDAKUTIBITI.
[0033] The mounting substrate 50 shown in drawing 1 (A) is produced by forming a superconduction pattern on the front face of the dielectric substrate 51 by the same approach as formation of superconducting circuit pattern 15a explained by drawing 3 (G), and superconducting thin film 15b. The height of the pad 55 by the side of the mounting substrate 50 is comparable as the thickness of wiring 56, and good.
[0034] Drawing 4 shows the temperature dependence of resistance between the pad 10 of drawing 1 (A), and a pad 55. An axis of abscissa expresses temperature with a unit "K", and an axis of ordinate expresses resistance with a unit "omega." Measurement of resistance was performed using 4 terminal method. In abbreviation 90K or less range which is the superconduction transition temperature of YBCO, it turns out that resistance is very low. By making YBCO into a superconductive state, it is possible to connect the superconducting circuit pattern on a superconducting circuit substrate and wiring on a mounting substrate by low

resistance.
[0035] In addition, judging from a current potential property, it will not be in a perfect superconductive state between a pad 10 and a pad 55, but it is thought that slight residual resistance remains. However, residual resistance of this level hardly affects actuation of a RF circuit. As a cause by which residual resistance remains, resistance resulting from the grain boundary of the interface between pads can be considered. It is thought that this resistance can be decreased by optimizing both surface treatment before contact of a pad.
[0036] Since the height of a pad 10 is about 10 micrometers, even when curvature is in the dielectric substrate 5 and the dielectric substrate 51 by the side of the mounting substrate 50, it is stabilized with sufficient repeatability and the superconducting circuit substrate 1 can be pasted up on the mounting substrate 50. Moreover, if a pad 10 is too thin, the superconducting material which forms a pad with heating at the time of adhesion is spread in a substrate, and mechanical and electric adhesion may not be obtained.
[0037] According to the experiment of artificers, good adhesion was not obtained when the height of a pad 10 was lower than 0.4 micrometers. Probably, it will be desirable to set the height of a pad 10 to 0.4 micrometers or more. Moreover, it is more desirable than the thickness of the sum total of touch-down electric conduction film 12a, dielectric thin film 13a, and superconducting circuit pattern 15a to make a pad 10 high. In addition, in order to secure sufficient adhesion, it is more desirable to set the height of a pad 10 to 1 micrometers or more.
[0038] Although drawing 1 explained the case where one superconducting circuit substrate was mounted on one mounting substrate, two or more superconducting circuit substrates may be mounted on one mounting substrate.
[0039] Drawing 5 shows the outline top view of the superconducting circuit equipment which mounted two or more superconducting circuit substrates on one mounting substrate. On the main front face of the mounting substrate 50, two or more superconducting circuit substrates 1 are mounted. Both adhesion is performed by the same approach as the adhesion in the case of the superconducting circuit equipment shown in drawing 1 (A).
[0040] On the field near [on the front face of main of the dielectric substrate 51 which constitutes the mounting substrate 50] the periphery section, two or more pads 57 for external connection are arranged. The pad 57 for external connection is connected to the pad for connection with the superconducting circuit substrate 1 by wiring 56. Wiring 58 connects the pads for connection with the superconducting circuit substrate 1.
[0041] Thus, improvement in packaging density can be aimed at by mounting two or more superconducting circuit substrates on one mounting substrate.
[0042] Next, with reference to drawing 6 , the superconducting circuit equipment by the 2nd example of this invention is explained.
[0043] Drawing 6 (A) shows the sectional view of the superconducting circuit equipment by the 2nd example, and drawing 6 (B) shows the top view. The sectional view in alternate long and short dash line A6-A6 of drawing 6 (B) is equivalent to the sectional view of drawing 6 (A).
[0044] The compound substrate 60 is constituted including the superconduction member 61 and two dielectric members 62. The superconduction member 61 is a plate with which a cross section consists of YBCO with a thickness of 0.3mm of trapezoidal shape. That is, the superconduction member 61 has the slant face which connects a top face and an inferior surface of tongue parallel to mutual, and a top face and an inferior surface of tongue. The angle of a base and a slant face to make is 45 degrees. Let the superconduction member 61 be crystal-face bearing where the c-axis becomes a top face and a perpendicular. If this crystal-face bearing is adopted, the invasion length of a magnetic field becomes short and can aim at the fall of the inductance of wiring.
[0045] Each of the dielectric member 62 is a plate which consists of MgO, and has the slant face which connects a top face and an inferior surface of tongue parallel to mutual, and a top face and an inferior surface of tongue. The slant face of two dielectric members 62 is pasted up on two slant faces of the superconduction member 61 through the superconducting thin film 64 which consists of YBCO, respectively. The top face of the dielectric member 62 demarcates one virtual flat surface with the top face of the superconduction member 61. That is, one flat top

face is demarcated by the superconduction member 61 and the dielectric member 62. On the inferior surface of tongue of the dielectric member 62, the superconducting thin film 63 which consists of YBCO is formed. The front face of a superconducting thin film 63 demarcates one virtual flat surface with the inferior surface of tongue of the superconduction member 61.
[0046] On the top face of the superconduction member 61 and the dielectric member 62, the dielectric thin film 65 with a thickness of 0.3 micrometers it is thin from MgO is formed. The front face of the compound substrate 60 is classified into the 1st field 75 corresponding to the top face of the superconduction member 61, the 2nd field 76 corresponding to a slant face, and the 3rd field 77 corresponding to the inferior surface of tongue of the dielectric member 62.
[0047] On the 1st field 75 of the front face of the compound substrate 60, with a thickness of 0.3 micrometers it is thin from YBCO superconducting circuit pattern 70A is formed. Superconducting circuit pattern 70A is a delay circuit, a multistage filter, a logical circuit, etc. On the 2nd and 3rd fields 76 and 77, with a thickness of 0.3 micrometers it is thin from YBCO drawer pattern 70B is formed. Drawer pattern 70B is connected to superconducting circuit pattern 70A. The width of face of the part arranged in the 2nd field 76 among drawer pattern 70B is thick as it separates from the 1st field 75.
[0048] The pattern width of face of superconducting circuit pattern 70A is 0.3 micrometers. The width of face of the part on the boundary of the 1st field 75 and the 2nd field 76 is 0.3 micrometers among drawer pattern 70B, and the width of face of the part on the boundary of the 2nd field 76 and the 3rd field 77 and the part in the 3rd field 77 is 0.3mm.
[0049] The compound substrate 60 is contained in the copper cavity 72. The superconduction member 61 and a superconducting thin film 63 are electrically connected to the inside of a cavity 72. The central conductor 71 of a high frequency connector is inserted into a cavity 72 via the through tube prepared in the cavity 72, and is stuck to drawer pattern 70B by pressure. The outer conductor of a high frequency connector is connected to a cavity 72.
[0050] the top face of the superconduction member 61, and superconducting thin films 63 and 64 -- touch-down -- the microstrip line structure used as a conductor is acquired. the touch-down from the main front face of the compound substrate 60, i.e., the front face of the dielectric thin film 65, -- the depth to a conductor is fixed in the 1st field 75. In the 2nd field 76, this depth is deep as it separates from the 1st field 75.
[0051] drawer pattern 70B -- the touch-down from the main front face of the compound substrate 60 -- the depth to a conductor becomes deep -- it is alike, and it follows and is thick according to the depth. For this reason, it becomes possible to make the characteristic impedance of a drawer pattern regularity mostly spatially. Since drawer pattern 70B is made large into the 3rd field 77, it can stick easily drawer pattern 70B and a central conductor 71 by pressure. Since the touch area of drawer pattern 70B and a central conductor 71 becomes large, both contact resistance can be reduced. Moreover, since the impedance of a connection has consistency, the reflection loss of a RF signal can be reduced.
[0052] Next, the manufacture approach of the superconducting circuit equipment by the 2nd example is explained. The superconduction member 61 and the dielectric member 62 are obtained by grinding aslant the edge of the single crystal substrate of YBCO, and the single crystal substrate of MgO, or cutting off aslant, respectively. Superconducting thin films 63 and 64 are formed of laser vacuum evaporationo or sputtering.
[0053] Adhesion with the dielectric member 62 and the superconduction member 61 in which superconducting thin films 63 and 64 were formed is performed by contacting both slant faces and overheating at about 920 degrees C.
[0054] Laser vacuum evaporationo can perform formation of the dielectric thin film 65. For example, laser vacuum evaporationo is performed on condition that the temperature of 740 degrees C, and pressure 200mTorr in an oxygen ambient atmosphere. Superconducting circuit pattern 70A and drawer pattern 70B are formed by carrying out patterning of this YBCO thin film, after forming a YBCO thin film. Laser vacuum evaporationo performs formation of a YBCO thin film. The condition is the same as that of the case of formation of the dielectric thin film 65.

[0055] In the above-mentioned example, although MgO was used as dielectric materials, using

YBCO as a superconducting material, other oxide superconducting materials and dielectric materials may be used. As an usable oxide superconducting material, the oxide superconducting material which used Nd, Eu, Ho, etc. instead of Y of YBCO is mentioned. Other than MgO, strontium titanate (STO), La0.35Sr0.65aluminum0.675Ta 0.325O3 (LAST), etc. are mentioned.
[0056] Although this invention was explained in accordance with the example above, this invention is not restricted to these. For example, probably, it will be obvious to this contractor for various modification, amelioration, combination, etc. to be possible.

[Translation done.]

* NOTICES *

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the sectional view and top view of superconducting circuit equipment by the 1st example.
[Drawing 2] It is the sectional view (the 1) of the substrate for explaining the manufacture approach of the superconducting circuit substrate used for the superconducting circuit equipment by the 1st example.
[Drawing 3] It is the sectional view (the 2) of the substrate for explaining the manufacture approach of the superconducting circuit substrate used for the superconducting circuit equipment by the 1st example.
[Drawing 4] It is the graph which shows the temperature dependence of resistance of the connection of pads it is temperature-independent from YBCO.
[Drawing 5] It is the top view of the superconducting circuit equipment which mounted two or more superconducting circuit substrates on one mounting substrate.
[Drawing 6] It is the sectional view and top view of superconducting circuit equipment by the 2nd example.
[Description of Notations]
1 Superconducting Circuit Substrate
5 Dielectric Substrate
6 Superconduction Thick Film
10 Pad
12 12b Superconducting thin film
12a Touch-down electric conduction film
13 13a Dielectric thin film
15a Superconducting circuit pattern
15b Superconducting thin film
50 Mounting Substrate
51 Dielectric Substrate
55 Pad
56 58 Wiring
57 Pad for External Connection
60 Central Conductor
61 Superconduction Member
62 Dielectric Member
63 64 Superconducting thin film
65 Dielectric Thin Film
70A Superconducting circuit pattern
70B Drawer pattern
71 Central Conductor
75 1st Field
76 2nd Field
77 3rd Field

[Translation done.]

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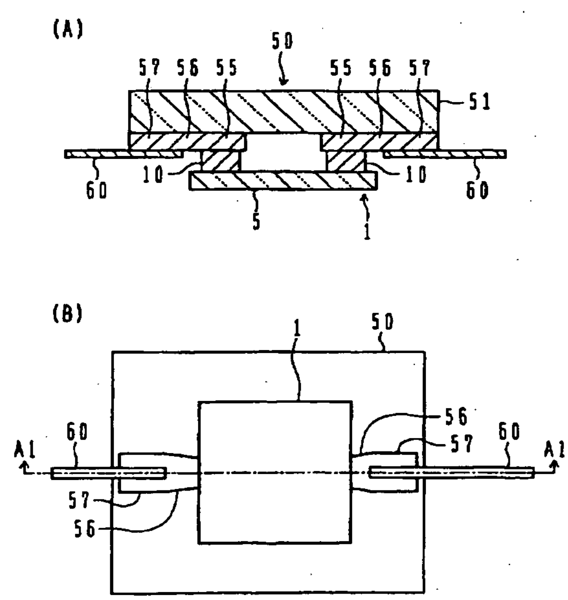
(71)出願人　000005223
富士通株式会社
神奈川県川崎市中原区上小田中４丁目１番１号
(71)出願人　391004481
財団法人国際超電導産業技術研究センター
東京都港区新橋５丁目34番３号　栄進開発ビル６階
(71)出願人　000002130
住友電気工業株式会社
大阪府大阪市中央区北浜四丁目５番33号
(74)代理人　100091340
弁理士　高橋　敬四郎

最終頁に続く

(54)【発明の名称】　超伝導回路装置及びその製造方法

(57)【要約】
【課題】　常電導ワイヤを用いることなく、超伝導回路基板を実装基板上に実装することが可能な超伝導回路装置を提供する。
【解決手段】　複数のパッドが、誘電体基板の主表面上に離散的に配置されている。パッドは、酸化物超伝導材料により形成されている。接地導電膜が、誘電体基板の主表面上に配置されている。接地導電膜は、酸化物超伝導材料により形成されている。誘電体膜が、接地導電膜の表面を覆う。超伝導回路パターンが、誘電体膜の表面上に配置されている。超伝導回路パターンは、パッドに接続されている。接地導電膜、誘電体膜、及び超伝導回路パターンの厚さの合計が、パッドの高さよりも小さい。

第１の実施例による超伝導回路装置



【特許請求の範囲】

【請求項１】　第１の誘電体基板と、
前記第１の誘電体基板の主表面上に離散的に配置され、酸化物超伝導材料により形成された複数の第１のパッドと、
前記第１の誘電体基板の主表面上に配置され、酸化物超伝導材料により形成された接地導電膜と、
前記接地導電膜の表面を覆う誘電体膜と、
前記誘電体膜の表面上に配置され、酸化物超伝導材料で形成され、前記第１のパッドに接続された超伝導回路パターンとを有し、
前記接地導電膜、前記誘電体膜、及び前記超伝導回路パターンの厚さの合計が、前記第１のパッドの高さよりも小さい超伝導回路装置。

【請求項２】　前記接地導電膜が、前記複数の第１のパッドのうち少なくとも１つの第１のパッドの表面を覆い、当該第１のパッドに電気的に接続されている請求項１に記載の超伝導回路装置。

【請求項３】　さらに、前記第１の誘電体基板よりも大きな第２の誘電体基板と、
前記第２の誘電体基板の主表面上に離散的に配置され、酸化物超伝導材料で形成された複数の第２のパッドであって、該第２の誘電体基板の主表面を前記第１の誘電体基板の主表面に対向させたとき、該第２のパッドが前記第１のパッドと対応する位置に配置されている第２のパッドと、
前記第２の誘電体基板の主表面上に配置され、酸化物超伝導材料で形成され、前記第２のパッドに接続された複数の配線とを有し、
前記第２のパッドの各々の上面が、対応する前記第１のパッドの上面に接着され、両者が電気的に導通している請求項１または２に記載の超伝導回路装置。

【請求項４】　第１の誘電体基板の主表面上に、第１の酸化物超伝導膜を形成する工程と、
前記第１の酸化物超伝導膜をパターニングし、離散的に分布する複数の第１のパッドを残す工程と、
前記第１の誘電体基板の主表面の一部の領域上に、酸化物超伝導材料からなる接地導電膜を形成する工程と、
前記接地導電膜の表面上に、誘電体薄膜を形成する工程と、
前記誘電体薄膜の表面上に、酸化物超伝導材料からなり、前記第１のパッドに接続された超伝導回路パターンを形成する工程とを有する超伝導回路装置の製造方法。

【請求項５】　前記第１のパッドの高さが、前記接地導電膜と誘電体薄膜と超伝導回路パターンとの合計の厚さよりも大きい請求項４に記載の超伝導回路装置の製造方法。

【請求項６】　前記接地導電膜を形成する工程が、
前記第１の誘電体基板の主表面及び前記第１のパッドを被覆するように、第２の酸化物超伝導薄膜を形成する工程と、
前記第１のパッドのうち少なくともひとつの第１のパッドが他の第１のパッドから電気的に分離されるように、かつ前記第２の酸化物超伝導薄膜が前記第１の誘電体基板の主表面の一部の領域上に残るように前記第２の酸化物超伝導薄膜をパターニングする工程とを含む請求項４または５に記載の超伝導回路装置の製造方法。

【請求項７】　さらに、主表面上に、酸化物超伝導材料で形成された複数の第２のパッドであって、該第２の誘電体基板の主表面を前記第１の誘電体基板の主表面に対向させたとき、該第２のパッドが前記第１のパッドと対応する位置に配置されている第２のパッドと、酸化物超伝導材料で形成され、前記第２のパッドに接続された複数の配線とを有する第２の誘電体基板を準備する工程と、
前記第１の誘電体基板と前記第２の誘電体基板とを、両者の主表面同士を対向させ、前記第２のパッドの各々の上面が、対応する前記第１のパッドの上面に接触するように配置する工程と、
前記第１の誘電体基板と前記第２の誘電体基板とを加熱し、前記第１のパッドとそれに対応する第２のパッドとを接着する工程とを含む請求項４～６のいずれかに記載の超伝導回路装置の製造方法。

【請求項８】　主表面が誘電体材料で形成され、主表面よりも下方に誘電体材料と酸化物超伝導材料との界面が形成された複合基板であって、該基板の主表面内に第１の領域とそれに隣接する第２の領域が画定され、該第１の領域においては、主表面から前記界面までの深さがほぼ一定であり、該第２の領域においては、主表面から前記界面までの深さが、前記第１の領域から離れるに従って深くなっている前記複合基板と、
前記複合基板の主表面内の前記第１の領域上に形成された超伝導回路パターンと、
前記複合基板の主表面内の前記第２の領域上に形成され、超伝導材料からなる引出パターンであって、該引出パターンは前記第１の領域と第２の領域との境界線と交差する方向に延在し、前記超伝導回路パターンに接続され、前記第１の領域から離れるに従って徐々に太くなっている前記引出パターンとを有する超伝導回路装置。

【請求項９】　前記複合基板が、
該複合基板の主表面に平行な上面、及び該上面に連続する斜面を有し、酸化物超伝導材料で形成された第１の部材と、
前記第１の部材の斜面に密着する斜面、及び前記第１の部材の上面とともにひとつの仮想平面を画定する上面を有し、誘電体材料で形成された第２の部材と、
前記第１の部材の上面と前記第２の部材の上面とを被覆する誘電体薄膜とを含む請求項８に記載の超伝導回路装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、超伝導材料を用いた電子回路を有する装置に関する。

【０００２】

【従来の技術】電気配線に超伝導材料を用いると、高周波電流に対する表面抵抗を低くすることができる。また、超伝導のトンネル効果素子を使用すると、消費電力の低減及び動作の高速化が可能になる。超伝導材料がこれらの優れた特性を有することから、高周波回路への超伝導材料の適用が進められている。超伝導転移温度が液化窒素温度を超える酸化物超伝導材料の発見以来、配線に酸化物超伝導材料を使用する試みがなされている。

【０００３】高周波回路では、信号を効率よく伝搬させるために、一般的にマイクロストリップライン構造が採用される。マイクロストリップライン構造の誘電層には、誘電特性（ｔａｎδ）に優れた材料が適している。また、誘電層上に酸化物超伝導薄膜をエピタキシャル成長させることができることが好ましい。これらの理由により、酸化物超伝導材料を用いたマイクロストリップライン構造の誘電層としてＭｇＯが用いられる場合が多い。

【０００４】

【発明が解決しようとする課題】配線の特性インピーダンスが空間的に変動すると、特性インピーダンスの変化点で信号の反射が生じ、信号の減衰や波形の歪が生ずる。信号の周波数が高くなると、信号の減衰や波形歪が顕著になる。

【０００５】マイクロストリップライン構造の特性インピーダンスは、誘電体層の誘電率、その厚さ、及び配線幅等によって近似的に決定される。誘電体層としてＭｇＯを用い、特性インピーダンスを５０Ω程度に設定するためには、誘電体層の厚さと配線幅とを同程度にしなければならない。

【０００６】超伝導集積回路装置の作製には、薄膜多層化技術が用いられる。この場合、薄膜表面の凹凸、結晶性、及び成長時間等から、通常、薄膜の厚さは１μｍ以下に設定される。ＭｇＯからなる誘電体層の厚さが１μｍ以下のときにマイクロストリップラインの特性インピーダンスを５０Ωにするためには、配線幅を１μｍ以下にする必要がある。

【０００７】一方、集積回路装置に接続される外部の配線は同軸構造を有し、その中心導体の太さは、細くても０．１ｍｍ程度である。集積回路装置の配線幅と同軸ケーブルの中心導体の太さとの大きな相違が、組み立てを困難にし、インピーダンス不整合による反射を大きくする。

【０００８】また、金属系の超伝導材料を使用する場合には、集積回路基板と実装基板との接続にフリップチップボンディングが用いられる。ところが、酸化物超伝導材料を用いる場合には、フリップチップボンディングを行うことが困難であり、常電導ワイヤを介した接続方法が採用されてきた。常電導ワイヤを用いると、超伝導材料同士を直接接続する場合に比べて、伝送特性が劣化してしまう。

【０００９】本発明の目的は、常電導ワイヤを用いることなく、超伝導回路基板を実装基板上に実装することが可能な超伝導回路装置及びその製造方法を提供することである。

【００１０】本発明の他の目的は、超伝導回路装置と外部線路との特性インピーダンスの整合を図ることが可能な超伝導回路装置を提供することである。

【００１１】

【課題を解決するための手段】本発明の一観点によると、第１の誘電体基板と、前記第１の誘電体基板の主表面上に離散的に配置され、酸化物超伝導材料により形成された複数の第１のパッドと、前記第１の誘電体基板の主表面上に配置され、酸化物超伝導材料により形成された接地導電膜と、前記接地導電膜の表面を覆う誘電体膜と、前記誘電体膜の表面上に配置され、酸化物超伝導材料で形成され、前記第１のパッドに接続された超伝導回路パターンとを有し、前記接地導電膜、前記誘電体膜、及び前記超伝導回路パターンの厚さの合計が、前記第１のパッドの高さよりも小さい超伝導回路装置が提供される。

【００１２】第１のパッドが比較的高いため、第１の誘電体基板や、それを実装するための実装基板に反りがあっても、第１のパッドと実装基板側のパッドとを安定して接着することができる。

【００１３】本発明の他の観点によると、第１の誘電体基板の主表面上に、第１の酸化物超伝導膜を形成する工程と、前記第１の酸化物超伝導膜をパターニングし、離散的に分布する複数の第１のパッドを残す工程と、前記第１の誘電体基板の主表面の一部の領域上に、酸化物超伝導材料からなる接地導電膜を形成する工程と、前記接地導電膜の表面上に、誘電体薄膜を形成する工程と、前記誘電体薄膜の表面上に、酸化物超伝導材料からなり、前記第１のパッドに接続された超伝導回路パターンを形成する工程とを有する超伝導回路装置の製造方法が提供される。

【００１４】超伝導回路パターンを形成する工程とは異なる工程で第１のパッドが形成される。このため、第１のパッドの高さを、超伝導回路パターンの厚さとは独立して設定することが可能になる。第１のパッドを高くすると、基板の反り等の影響を受けにくくなる。

【００１５】本発明の他の観点によると、主表面が誘電体材料で形成され、主表面よりも下方に誘電体材料と酸化物超伝導材料との界面が形成された複合基板であって、該基板の主表面内に第１の領域とそれに隣接する第２の領域が画定され、該第１の領域においては、主表面から前記界面までの深さがほぼ一定であり、該第２の領

域においては、主表面から前記界面までの深さが、前記第１の領域から離れるに従って深くなっている前記複合基板と、前記複合基板の主表面内の前記第１の領域上に形成された超伝導回路パターンと、前記複合基板の主表面内の前記第２の領域上に形成され、超伝導材料からなる引出パターンであって、該引出パターンは前記第１の領域と第２の領域との境界線と交差する方向に延在し、前記超伝導回路パターンに接続され、前記第１の領域から離れるに従って徐々に太くなっている前記引出パターンとを有する超伝導回路装置が提供される。

【００１６】この超伝導回路装置は、複合基板の誘電体材料と超伝導材料との界面を接地導体面とするマイクロストリップライン構造を有する。引出パターンと接地導体面との間隔が広くなるに従って、引出パターンが太くなっている。このため、引出パターンの特性インピーダンスの空間的な変動を少なくすることができる。引出パターンの太い部分に、高周波コネクタ等の導線を容易に接着することができる。

【００１７】

【発明の実施の形態】図１～図４を参照して、本発明の第１の実施例による超伝導回路装置について説明する。

【００１８】図１（Ａ）は、第１の実施例による超伝導回路装置の概略断面図を示し、図１（Ｂ）は平面図を示す。図１（Ｂ）の一点鎖線Ａ１－Ａ１における断面図が、図１（Ａ）に相当する。超伝導回路装置は、基本的に超伝導回路基板１と実装基板５０とを含んで構成される。超伝導回路基板１は、ＭｇＯからなる誘電体基板５と$YBa_2Cu_3O_{7-d}$（ＹＢＣＯ）からなる複数の第１のパッド１０を含んで構成される。ここでｄは、酸素の欠損量である。複数の第１のパッド１０は、誘電体基板５の主表面上に離散的に分布する。超伝導回路基板１のより詳細な構成については、図２及び図３を参照して後述する。

【００１９】実装基板５０は、ＭｇＯからなる誘電体基板５１と、その主表面上に形成されたＹＢＣＯからなる複数の第２のパッド５５、配線５６及び外部接続用パッド５７を含んで構成される。第２のパッド５５は、誘電体基板５と５１とを、それらの主表面同士を対向させて配置したとき、第１のパッド１０に対応する位置に配置されている。第２のパッド５５は、それぞれ配線５６を介して外部接続用パッド５７に電気的に接続されている。

【００２０】第１のパッド１０の各々の上面が、当該第１のパッド１０に対応する第２のパッド５５の上面に接着されている。パッド同士の接着は、両者を接触させて、酸素雰囲気中で、９２０℃で２時間加熱することにより行われる。９２０℃は、ＹＢＣＯの焼結温度である。なお、パッド同士を加圧することにより、加熱温度を下げることができる。例えば、ステンレスバネを用いて加圧した場合、９００℃の温度で両者が接着した。

【００２１】外部接続用パッド５７に、高周波コネクタの中心導体６０が圧着されている。なお、高周波コネクタの外部導体は、実装基板５０の配線パターンのグランド面に接続する。高周波コネクタに、外部信号線が接続される。外部信号線として、通常、同軸ケーブルが使用される。

【００２２】次に、図２及び図３を参照して、超伝導回路基板１の製造方法について説明する。

【００２３】図２（Ａ）に示すように、ＭｇＯからなる誘電体基板５を準備する。誘電体基板５の主表面上に、ＹＢＣＯからなる厚さ１０μｍの超伝導厚膜６を形成する。超伝導厚膜６の形成は、液相結晶成長（ＬＰＥ）により行われる。ＭｇＯ基板上にＹＢＣＯ膜をＬＰＥ法を用いて形成する方法は、例えば特開平７－３３５９０号公報に詳細に説明されている。以下、超伝導厚膜６の形成方法を簡単に説明する。

【００２４】まず、誘電体基板５の主表面上に、プラズマ蒸着法により厚さ０．０１～１μｍのＹＢＣＯ膜を成長させる。プラズマ蒸着法により形成されたＹＢＣＯ膜の上に、ＬＰＥ法を用いて厚いＹＢＣＯ膜を成長させる。溶媒としてＢａＯとＣｕＯとの混合融液を用いる。ＢａとＣｕとのモル比は３：５である。溶質供給物質としてY_2BaCuO_5を用いる。溶質と溶媒を入れたるつぼを加熱し、溶質と溶媒を溶融させる。その後、表面温度を１０００℃に、るつぼ底部を１０１０℃に調整する。この状態では、液体状態の溶媒の下部に溶質供給物質が沈殿している。溶媒中には、溶質供給物質が溶解している。

【００２５】この溶液にプラズマ蒸着法で形成されたＹＢＣＯ膜の表面を接触させ、回転数を毎分１００回転としてＹＢＣＯ厚膜を成長させる。プラズマ蒸着法で形成されたＹＢＣＯ膜が種結晶となる。成長後のＹＢＣＯ厚膜の厚さが１０μｍよりもやや厚くなるように、ＹＢＣＯ厚膜を成長させる。成長後、ＹＢＣＯ厚膜の表面を研磨して、厚さ１０μｍの超伝導厚膜６を形成する。

【００２６】図２（Ｂ）に示すように、超伝導厚膜６をパターニングして、複数のパッド１０を残す。パッド１０は、誘電体基板５の主表面上に離散的に分布する。超伝導厚膜６のパターニングは、例えば硝酸を用いたウェットエッチングにより行う。各パッド１０の直径は、例えば０．５ｍｍ程度である。

【００２７】図２（Ｃ）に示すように、誘電体基板５の主表面及びパッド１０の表面を覆うように、ＹＢＣＯからなる厚さ０．２～０．３μｍの超伝導薄膜１２を形成する。超伝導薄膜１２の形成は、例えば、レーザ蒸着により行う。

【００２８】図２（Ｄ）に示すように、超伝導薄膜１２をパターニングする。誘電体基板５の主表面の、パッド１０の配置されていない領域上に、接地導電膜１２ａが残る。パッド１０の各々の表面上にも、超伝導薄膜１２

ｂが残る。接地導電膜１２ａは、少なくともひとつのパッド１０を覆う超伝導薄膜１２ｂに連続する。また、少なくともひとつのパッド１０は、接地導電膜１２ａから電気的に分離される。図２（Ｂ）においては、右側のパッド１０を覆う超伝導薄膜１２ｂが接地導電膜１２ａに連続し、左側のパッド１０が接地導電膜１２ａから電気的に分離されている。

【００２９】図３（Ｅ）に示すように、基板上に、ＭｇＯからなる厚さ０．２～０．３μｍの誘電体薄膜１３を形成する。誘電体薄膜１３の形成は、例えばレーザ蒸着またはスパッタリング等により行うことができる。

【００３０】図３（Ｆ）に示すように、パッド１０を覆う誘電体薄膜１３を除去する。接地導電膜１２ａを覆う誘電体薄膜１３ａが残る。誘電体薄膜１３の部分的な除去は、残すべき部分をレジストパターンで覆って、露出した部分をイオンミリングすることにより行うことができる。

【００３１】図３（Ｇ）に示すように、誘電体薄膜１３ａの表面上に、ＹＢＣＯからなる超伝導回路パターン１５ａを形成するとともに、パッド１０を覆う超伝導薄膜１２ｂの上に、さらにＹＢＣＯからなる超伝導薄膜１５ｂを積層する。超伝導回路パターン１５ａ及び超伝導薄膜１５ｂは、基板上にＹＢＣＯ薄膜を成長させた後、このＹＢＣＯ薄膜をパターニングすることにより形成される。超伝導回路パターン１５ａ及び超伝導薄膜１５ｂの厚さは、０．２～０．３μｍである。

【００３２】図２（Ａ）から図３（Ｇ）までの工程を経て、マイクロストリップライン構造の超伝導回路基板１が作製される。超伝導回路の例として、論理回路が挙げられる。比較回路の一構成例が、ＩＥＥＥトランザクション オン アプライド スーパーコンダクティビティの第７巻第２号（１９９７年６月）（ＩＥＥＥ ＴＲＡＮＳＡＣＴＩＯＮＳ ＯＮ ＡＰＰＬＩＥＤ ＳＵＰＥＲＣＯＮＤＵＣＴＩＶＩＴＹ，ＶＯＬ．７，ＮＯ．２，ＪＵＮＥ １９９７）の２９８７～２９９２頁に記載されている。

【００３３】図１（Ａ）に示す実装基板５０は、誘電体基板５１の表面上に、図３（Ｇ）で説明した超伝導回路パターン１５ａ及び超伝導薄膜１５ｂの形成と同様の方法で超電導パターンを形成することにより作製される。実装基板５０側のパッド５５の高さは、配線５６の厚さと同程度でよい。

【００３４】図４は、図１(Ａ)のパッド１０とパッド５５との間の抵抗の温度依存性を示す。横軸は温度を単位「Ｋ」で表し、縦軸は抵抗を単位「Ω」で表す。抵抗の測定は、４端子法を用いて行った。ＹＢＣＯの超伝導転移温度である約９０Ｋ以下の範囲において、抵抗が非常に低くなっていることがわかる。ＹＢＣＯを超伝導状態にすることにより、超伝導回路基板上の超伝導回路パターンと実装基板上の配線とを、低抵抗で接続することが可能である。

【００３５】なお、電流電圧特性から判断すると、パッド１０とパッド５５との間は、完全な超伝導状態にはなっておらず、わずかな残留抵抗が残っていると思われる。ただし、この程度の残留抵抗は、高周波回路の動作にほとんど影響を及ぼさない。残留抵抗が残る原因として、パッド間の界面の結晶粒界に起因する抵抗が考えられる。この抵抗は、パッドの接触前に、両者の表面処理を最適化することにより減少させることができると考えられる。

【００３６】パッド１０の高さが１０μｍ程度であるため、誘電体基板５や、実装基板５０側の誘電体基板５１に反りがある場合でも、再現性よく安定して超伝導回路基板１を実装基板５０上に接着することができる。また、パッド１０が薄すぎると、接着時の加熱によりパッドを形成する超伝導材料が基板内に拡散し、機械的及び電気的な接着が得られない場合がある。

【００３７】発明者らの実験によると、パッド１０の高さが０．４μｍよりも低い場合、良好な接着が得られなかった。パッド１０の高さを０．４μｍ以上にすることが好ましいであろう。また、接地導電膜１２ａ、誘電体薄膜１３ａ、及び超伝導回路パターン１５ａの合計の厚さよりも、パッド１０を高くすることが好ましい。なお、十分な接着を確保するためには、パッド１０の高さを１μｍ以上にすることがより好ましい。

【００３８】図１では、１枚の実装基板上に１枚の超伝導回路基板を実装する場合を説明したが、１枚の実装基板上に複数枚の超伝導回路基板を実装してもよい。

【００３９】図５は、１枚の実装基板上に複数枚の超伝導回路基板を実装した超伝導回路装置の概略平面図を示す。実装基板５０の主表面上に、複数の超伝導回路基板１が実装されている。両者の接着は、図１（Ａ）に示す超伝導回路装置の場合の接着と同じ方法で行われる。

【００４０】実装基板５０を構成する誘電体基板５１の主表面の外周部近傍の領域上に、複数の外部接続用パッド５７が配置されている。外部接続用パッド５７は、配線５６により、超伝導回路基板１との接続用パッドに接続されている。配線５８が、超伝導回路基板１との接続用パッド同士を接続する。

【００４１】このように、１枚の実装基板上に複数の超伝導回路基板を実装することにより、実装密度の向上を図ることができる。

【００４２】次に、図６を参照して、本発明の第２の実施例による超伝導回路装置について説明する。

【００４３】図６（Ａ）は、第２の実施例による超伝導回路装置の断面図を示し、図６（Ｂ）は、その平面図を示す。図６（Ｂ）の一点鎖線Ａ６－Ａ６における断面図が図６（Ａ）の断面図に相当する。

【００４４】複合基板６０が、超伝導部材６１と２つの誘電体部材６２とを含んで構成される。超伝導部材６１

は、断面が台形状の、厚さ０．３ｍｍのＹＢＣＯからなる板である。すなわち、超伝導部材６１は、相互に平行な上面と下面、及び上面と下面とを接続する斜面とを有する。底面と斜面とのなす角は、例えば４５度である。超伝導部材６１は、そのｃ軸が上面と垂直になるような結晶面方位とされている。この結晶面方位を採用すると、磁場の侵入長が短くなり配線のインダクタンスの低下を図ることができる。

【００４５】誘電体部材６２の各々は、ＭｇＯからなる板であり、相互に平行な上面と下面、及び上面と下面とを接続する斜面とを有する。２つの誘電体部材６２の斜面は、それぞれ、ＹＢＣＯからなる超伝導薄膜６４を介して超伝導部材６１の２つの斜面に接着されている。誘電体部材６２の上面は、超伝導部材６１の上面とともにひとつの仮想平面を画定する。すなわち、超伝導部材６１と誘電体部材６２とにより、１つの平坦な上面が画定される。誘電体部材６２の下面上に、ＹＢＣＯからなる超伝導薄膜６３が形成されている。超伝導薄膜６３の表面が、超伝導部材６１の下面とともにひとつの仮想平面を画定する。

【００４６】超伝導部材６１と誘電体部材６２の上面上に、ＭｇＯからなる厚さ０．３μｍの誘電体薄膜６５が形成されている。複合基板６０の表面が、超伝導部材６１の上面に対応する第１の領域７５、斜面に対応する第２の領域７６、及び誘電体部材６２の下面に対応する第３の領域７７に区分される。

【００４７】複合基板６０の表面の第１の領域７５の上に、ＹＢＣＯからなる厚さ０．３μｍの超伝導回路パターン７０Ａが形成されている。超伝導回路パターン７０Ａは、例えば遅延回路、多段フィルタ、論理回路等である。第２及び第３の領域７６及び７７の上に、ＹＢＣＯからなる厚さ０．３μｍの引出パターン７０Ｂが形成されている。引出パターン７０Ｂは、超伝導回路パターン７０Ａに接続されている。引出パターン７０Ｂのうち第２の領域７６内に配置された部分の幅が、第１の領域７５から離れるに従って太くなっている。

【００４８】超伝導回路パターン７０Ａのパターン幅は０．３μｍである。引出パターン７０Ｂのうち、第１の領域７５と第２の領域７６との境界上の部分の幅は０．３μｍであり、第２の領域７６と第３の領域７７との境界上の部分及び第３の領域７７内の部分の幅は０．３ｍｍである。

【００４９】複合基板６０は、銅製のキャビティ７２内に収納されている。超伝導部材６１及び超伝導薄膜６３は、キャビティ７２の内面に電気的に接続される。高周波コネクタの中心導体７１が、キャビティ７２に設けられた貫通孔を経由してキャビティ７２内に挿入され、引出パターン７０Ｂに圧着されている。高周波コネクタの外部導体は、キャビティ７２に接続される。

【００５０】超伝導部材６１の上面、超伝導薄膜６３及び６４を接地導体とするマイクロストリップライン構造が得られる。複合基板６０の主表面、すなわち誘電体薄膜６５の表面から、接地導体までの深さは、第１の領域７５においては一定である。第２の領域７６においては、この深さは、第１の領域７５から離れるに従って深くなっている。

【００５１】引出パターン７０Ｂは、複合基板６０の主表面から接地導体までの深さが深くなるに従って、その深さに応じて太くなっている。このため、引出パターンの特性インピーダンスを空間的にほぼ一定にすることが可能になる。引出パターン７０Ｂは、第３の領域７７内において広くされているため、引出パターン７０Ｂと中心導体７１とを容易に圧着することができる。引出パターン７０Ｂと中心導体７１との接触面積が大きくなるため、両者の接触抵抗を低減することができる。また、接続部のインピーダンスが整合しているため、高周波信号の反射損失を低減することができる。

【００５２】次に、第２の実施例による超伝導回路装置の製造方法について説明する。超伝導部材６１及び誘電体部材６２は、それぞれ、ＹＢＣＯの単結晶基板及びＭｇＯの単結晶基板の縁を斜めに研磨するか、または斜めに切り落とすことによって得られる。超伝導薄膜６３及び６４は、レーザ蒸着またはスパッタリングにより形成される。

【００５３】超伝導薄膜６３及び６４を形成した誘電体部材６２と超伝導部材６１との接着は、両者の斜面同士を接触させて９２０℃程度に過熱することにより行われる。

【００５４】誘電体薄膜６５の形成は、レーザ蒸着により行うことができる。例えば、酸素雰囲気中で、温度７４０℃、圧力２００ｍＴｏｒｒの条件でレーザ蒸着を行う。超伝導回路パターン７０Ａ及び引出パターン７０Ｂは、ＹＢＣＯ薄膜を形成した後、このＹＢＣＯ薄膜をパターニングすることにより形成される。ＹＢＣＯ薄膜の形成は、レーザ蒸着により行う。その条件は、誘電体薄膜６５の形成の場合と同様である。

【００５５】上記実施例では、超伝導材料としてＹＢＣＯを用い、誘電体材料としてＭｇＯを用いたが、他の酸化物超伝導材料や誘電体材料を用いてもよい。使用可能な酸化物超伝導材料として、ＹＢＣＯのＹの代わりにＮｄ、Ｅｕ、Ｈｏ等を用いた酸化物超伝導材料が挙げられる。ＭｇＯの他に、チタン酸ストロンチウム（ＳＴＯ）や$La_{0.35}Sr_{0.65}Al_{0.675}Ta_{0.325}O_3$（ＬＡＳＴ）等が挙げられる。

【００５６】以上実施例に沿って本発明を説明したが、本発明はこれらに制限されるものではない。例えば、種々の変更、改良、組み合わせ等が可能なことは当業者に自明であろう。

【００５７】

【発明の効果】以上説明したように、本発明によれば、

超伝導回路基板のパッドを高くすることにより、再現性よく超伝導回路基板を実装基板上に接着することができる。マイクロストリップライン構造の配線と接地導体との距離を変化させることにより、配線幅を変化させても、その特性インピーダンスを一定に保つことができる。外部との接続部の配線幅を太くすることにより、配線と外部の導体との接着を容易に行うことが可能になる。

【図面の簡単な説明】

【図１】第１の実施例による超伝導回路装置の断面図及び平面図である。

【図２】第１の実施例による超伝導回路装置に使用される超伝導回路基板の製造方法を説明するための基板の断面図（その１）である。

【図３】第１の実施例による超伝導回路装置に使用される超伝導回路基板の製造方法を説明するための基板の断面図（その２）である。

【図４】ＹＢＣＯからなるパッド同士の接続部の抵抗の温度依存性を示すグラフである。

【図５】１枚の実装基板上に複数の超伝導回路基板を実装した超伝導回路装置の平面図である。

【図６】第２の実施例による超伝導回路装置の断面図及び平面図である。

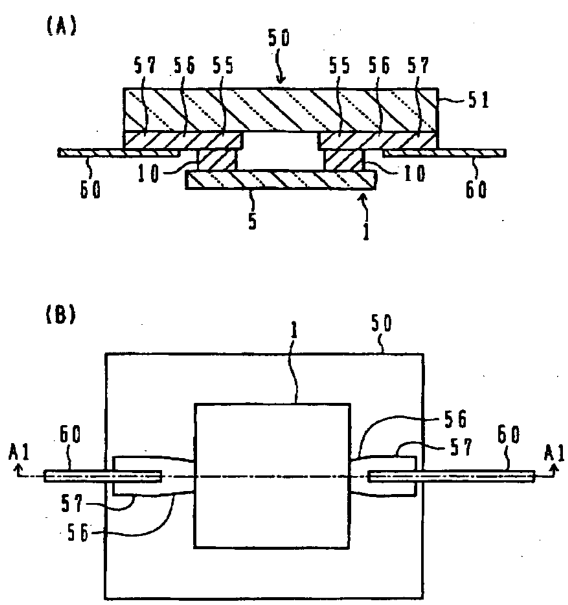
【符号の説明】

１　超伝導回路基板　＊

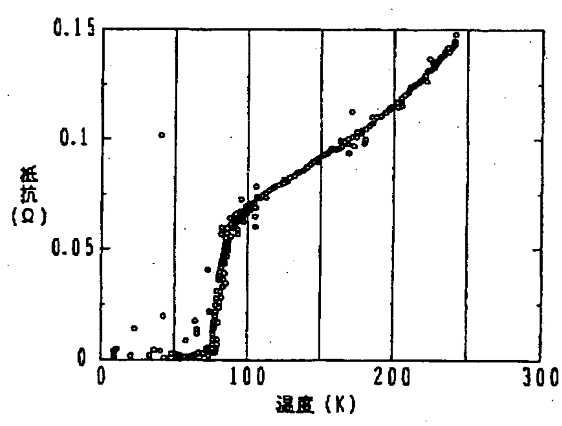
＊５　誘電体基板
６　超伝導厚膜
１０　パッド
１２、１２ｂ　超伝導薄膜
１２ａ　接地導電膜
１３、１３ａ　誘電体薄膜
１５ａ　超伝導回路パターン
１５ｂ　超伝導薄膜
５０　実装基板
５１　誘電体基板
５５　パッド
５６、５８　配線
５７　外部接続用パッド
６０　中心導体
６１　超伝導部材
６２　誘電体部材
６３、６４　超伝導薄膜
６５　誘電体薄膜
７０Ａ　超伝導回路パターン
７０Ｂ　引出パターン
７１　中心導体
７５　第１の領域
７６　第２の領域
７７　第３の領域

【図１】

第１の実施例による超伝導回路装置

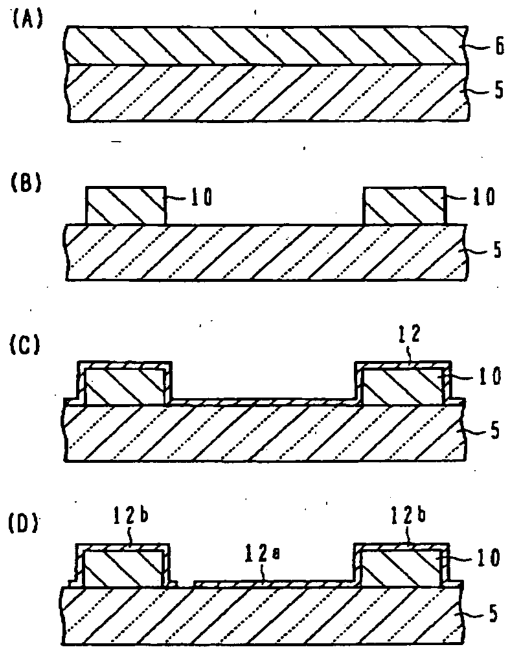


【図４】



【図２】

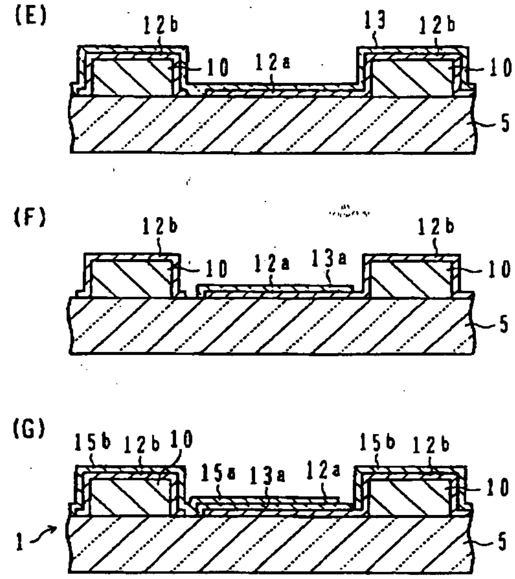
第１の実施例による製造方法（その１）



5：誘電体基板　12,12b：超伝導薄膜
6：超伝導厚膜　12a：接地薄膜
10：パッド

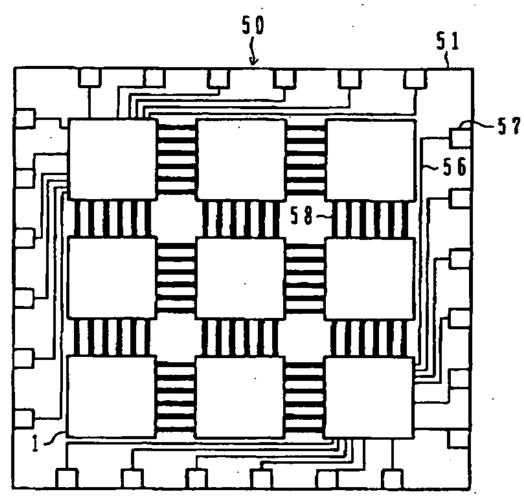
【図３】

第１の実施例による製造方法（その２）



13：誘電体薄膜
15a：超伝導回路パターン
15b：超伝導薄膜

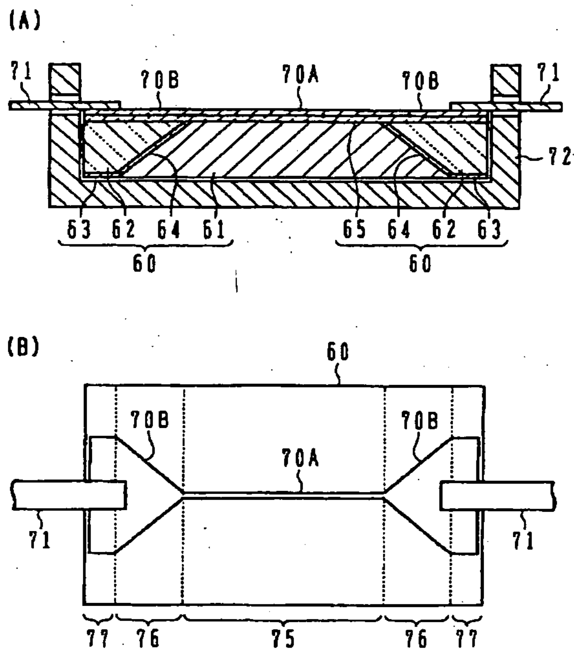
【図５】



1：超伝導回路基板
50：実装基板
51：誘電体基板
56,58：配線
57：　外部接続用パッド

【図６】

第２の実施例による超伝導回路装置



フロントページの続き

(72)発明者　榎本　陽一
東京都江東区東雲一丁目14番３号　財団法人国際超電導産業技術研究センター　超電導工学研究所内

(72)発明者　鈴木　秀雄
東京都江東区東雲一丁目14番３号　財団法人国際超電導産業技術研究センター　超電導工学研究所内

(72)発明者　和泉　輝郎
東京都江東区東雲一丁目14番３号　財団法人国際超電導産業技術研究センター　超電導工学研究所内

(72)発明者　塩原　融
東京都江東区東雲一丁目14番３号　財団法人国際超電導産業技術研究センター　超電導工学研究所内

(72)発明者　飯山　道朝
東京都江東区東雲一丁目14番３号　財団法人国際超電導産業技術研究センター　超電導工学研究所内

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